Submitted: 26 June, 2023 Accepted: 09 August, 2023 Published: 03 January, 2024 DOI:10.22514/jocpd.2024.012

Journal of Clinical Pediatric Dentistry

ORIGINAL RESEARCH

The predictability of arch expansion with the Invisalign First system in children with mixed dentition: a retrospective study

Chi Hoon Kim[1], Sang-Jin Moon[2], Chung-Min Kang[1], Je Seon Song[1,*]

[1]Department of Pediatric Dentistry, College of Dentistry, Yonsei University, 03722 Seoul, Republic of Korea
[2]Yongin Junior Dental Clinic, 17051 Yongin, Republic of Korea

***Correspondence**
SONGJS@yuhs.ac
(Je Seon Song)

Abstract

This study aimed to quantify the predictability of arch expansion in children with early mixed dentition treated with the Invisalign First® system and evaluate the clinical factors for the predictability of arch expansion. Pretreatment, predicted and posttreatment digital models from Invisalign's ClinCheck® software were obtained for 90 children with mean (standard deviation) age of 8.42 (0.93) who planned arch expansion. Arch width measurements were collected using Invisalign's arch width table. The predictability of expansion was calculated by comparing the amount of expansion achieved with the predicted expansion. Linear regression analysis was used to evaluate clinical factors associated with predictability of expansion. The predictability of the expansion of the maxillary teeth was as follows: 71.1% primary canines (n = 55), 67.5% first primary molars (n = 46), 65.2% second primary molars (n = 79), and 53.4% first permanent molars (n = 90); the predictability of the expansion of the mandibular teeth was 81.1% primary canines (n = 31), 81.2% first primary molars (n = 51), 77.8% second primary molars (n = 80), and 69.4% first permanent molars (n = 90). The predictability of arch expansion was significantly higher in the mandibular arch compared to the maxillary arch and significantly lower in the permanent first molar than in the other primary teeth. Predictability decreased significantly as the amount of predicted expansion per aligner increased in the upper and lower permanent first molars, primary second molars, and upper primary canines. Predictability significantly increased when buccal or palatal attachments were placed on the bilateral side compared to cases without attachment at the upper permanent first and primary second molars. The predictability of arch expansion using the Invisalign First® system varies according to arch and tooth type. The amount of predicted expansion per aligner and the number of attachments to the maxillary teeth are potential clinical factors that can affect the predictability of expansion.

Keywords

Arch expansion; Mixed dentition; Invisalign first; Predictability

1. Introduction

Orthodontic treatment in children with mixed dentition is important because early treatment can not only correct occlusion but also ensures normal tooth development. Arch expansion is an important mechanism that is often used in children with mixed dentition to correct transverse skeletal and dental discrepancies or to increase the arch perimeter [1]. Expansion of a compressed arch as a method of resolving crowding can increase the arch length, thus providing more space for tooth alignment. It can also improve the transverse dimension of the smile or correct posterior dentoalveolar crossbites [2, 3].

Conventional fixed or removable devices with wires and expansion screws are typically used for arch expansion. However, an increasing number of patients are seeking more aesthetic and comfortable alternatives to conventional orthodontic appliances [4]. With decades of improvements in computer-aided design and manufacturing (CAD/CAM) and dental materials, orthodontic treatment using clear aligners has become increasingly common in many cases, including arch expansion, particularly in adults and teenagers [5–7]. Compared with fixed appliances, clear aligners have disadvantages related to the inefficiency and unreliability of specific type of tooth movements [8], which can lead to prescribing additional sets of aligner and extended treatment times. However, it has been also reported that clear aligners have advantage such as esthetics [9], less discomfort [10] and better oral hygiene [11]. In 2018, Align Technology Inc. introduced the Invisalign First® (Align Technology Inc., Tempe, AZ, USA) clear aligners designed specifically for younger patients in early mixed dentition. According to Align Technology, Inc., this device can be used to perform phase I orthodontic treatment, including the correction of a narrow arch.

Several studies have reported on the predictability of arch expansion using the Invisalign® system. However, most of the studies were conducted on adolescents or adults with permanent dentition [12–15], and there are few reports on the early mixed dentition stage where the Invisalign First® system can be used [16, 17]. In addition, there are few studies on the clinical factors that can affect arch expansion [14].

Therefore, the aim of this study was to (1) quantify the predictability of arch expansion in children with early mixed dentition treated with the Invisalign First® system and (2) evaluate the clinical factors for predicting arch expansion.

2. Materials and methods

2.1 Patient selection

A total of 164 consecutive patient records treated with Invisalign First® between January 2020 and December 2022 were reviewed for this study. Records were sourced from a single private practice in Yong-in, Gyeonggi-do, Republic of Korea by a pediatric dentist who was highly experienced with Invisalign. A total of 90 patients were selected based on the following inclusion criteria: (1) age between 7 and 9 years old, (2) mixed dentition, (3) fully erupted first permanent molars, with good tooth contour and sufficient height of clinical crowns, (4) planned arch expansion with Invisalign First system, (5) aligners changed every 7 days, (6) good compliance during treatment as assessed by the practitioner, and (7) pretreatment and posttreatment intraoral scan data were available. Patients with one of the following characteristics were excluded from the study: (1) missing primary canines or molars prior to treatment, (2) previous orthodontic treatment, (3) presence of craniofacial deformities, systemic diseases that can affect tooth movement, and (4) use of other auxiliary appliances.

2.2 Clinical data collection

The dental records of each patient were obtained from an electronic clinical database, and the factors potentially affecting treatment outcomes were recorded. These included both sociodemographic and clinical variables: sex (boys or girls); age (years); number of pulp-treated tooth (0, 1 or 2); number of crown restoration (0, 1 or 2); number and position of attachments (no attachment, 1 attachment at unilateral tooth, 1 attachment at buccal surface of bilateral teeth, or 2 attachments at buccal and palatal surface of bilateral teeth); number of eruption compensation wells on appliance design (0, 1, 2 or 3); and amount of predicted expansion (mm); number of aligner.

2.3 Evaluation of predictability of arch expansion

After obtaining patient consent, six digital models were obtained for each patient: (1) pretreatment (initial), (2) predicted, and (3) posttreatment models for both the maxillary and mandibular arches. Pretreatment and posttreatment models were obtained using the iTero® (Align Technology Inc., Tempe, AZ, USA) intraoral scanner, and predicted model from the first ClinCheck® (Align Technology Inc., Tempe, AZ, USA) treatment plan. For each model, four arch-width measurements were taken at the maxillary and mandibular primary canines, first and second primary molars, and first permanent molars. Measurements were taken from each tooth and its antimere at the point on the occlusal surface of each tooth where the long axis intersected the occlusal surface, using the arch width table provided by ClinCheck® software (Invisalign's proprietary software). The arch width table provided by ClinCheck® software automatically calculated the arch width measurements based on the criteria mentioned above. Predictability of arch expansion was calculated by comparing predicted expansion (predicted arch width - initial arch width) to achieved expansion (post treatment arch width - initial arch width). Predictability was defined as the percentage of predicted expansion achieved: predictability = (achieved expansion)/(predicted expansion) $\times$ 100% (Fig. 1).

2.4 Statistical analyses

All statistical analyses were performed using R (version 3.6.1; R Foundation for Statistical Computing, Vienna, Austria) with predictability of arch expansion as the dependent variable. Data distribution was determined using the Shapiro-Wilk test. Student's *t*-test were used to assess the significance of the differences in predictability between the arch. Analysis of variance (ANOVA) and Tukey's *post-hoc* test were used to assess the significance of the differences in predictability among the teeth. Univariate linear regression analyses were performed to identify significant factors that could affect the predictability. Factors with $p < 0.05$ in the univariate analysis were selected for the multivariate regression model. The significance level was set at $p < 0.05$ all tests.

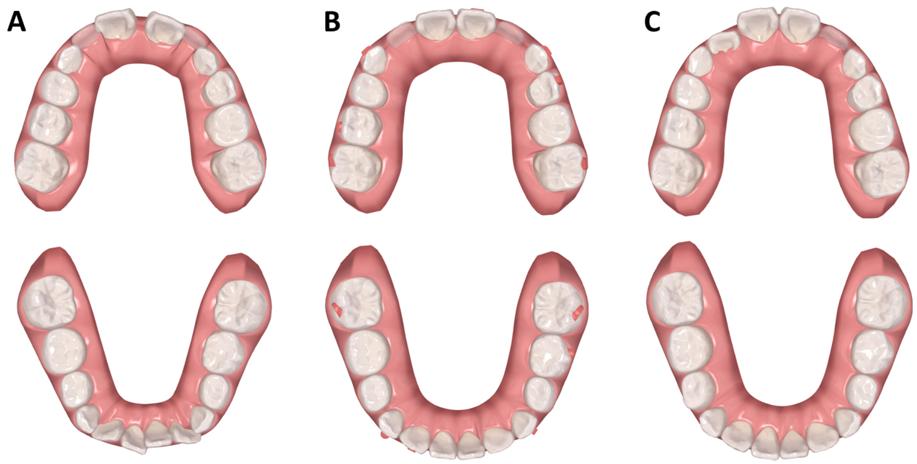
3. Results

3.1 Description of study population

A total of 720 teeth and their antimeres from 90 patients were recruited for this study. However, 204 deciduous teeth exfoliated due to eruption of succedaneous permanent teeth during the treatment period, leaving a sample size of 90 patients with 516 teeth and their antimeres. The characteristics of the study population according to teeth and clinical variables are shown in Table 1. The sample size consisted of 42 boys and 48 girls with a mean (standard deviation) age of the children was 8.42 (0.93). Most teeth were not treated endodontically or restored with a crown. In the treatment plan, most teeth had one attachment on each side. The mean (standard deviation) number of aligners was 25.11 (6.59).

3.2 Predictability of arch expansion measurement

The distribution of the predictability of arch expansion according to the arch and teeth are shown in Fig. 2. The mean (standard deviation) predictability according to arch was: 63.85 (21.47) % for maxilla, 76.25 (20.14) % for mandible. The mean (standard deviation) predictability of maxillary tooth expansion was: 71.1 (19.5) % for primary canines, 67.5 (18.1) % for first primary molars, 65.2 (17.4) % for second primary



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	(1) Pretreatment Initial	(2) Predicted Align final	(3) Posttreatment Initial	Predictability $\frac{(3)-(1)}{(2)-(1)}$ x 100 (%)
Maxilla				
53 – 63	30.3	36.7	35.0	73.4
54 – 64	34.5	38.6	37.3	68.3
55 – 65	38.5	42.0	41.1	74.3
16 – 26	43.3	45.9	45.5	84.6
Mandible				
83 – 73	25.2	29.4	29.3	97.6
84 – 74	28.7	33.6	33.6	100.0
85 – 75	32.6	37.8	37.1	86.5
46 – 36	38.2	40.9	40.4	81.5

FIGURE 1. An example of measuring arch width and calculating predictability of arch expansion. (A) Pretreatment digital models. (B) Predicted digital models. (C) Posttreatment digital models. (D) Measurements of arch width using arch width table on the ClinCheck® software and calculation of predictability of arch expansion.

molars, 53.4 (25.8) % for permanent first molars. The predictability of the expansion of the mandibular teeth was: 81.1 (17.4) % for primary canines, 81.2 (17.1) % for first primary molars, 77.8 (18.4) % for second primary molars, and 69.4 (21.5) % for first permanent molars. The predictability of arch expansion was significantly higher in the mandibular arch than in the maxillary arch ($p < 0.001$) and was significantly lower in the permanent first molar compared to primary canine and the first and second primary molars in both the arches.

3.3 Linear regression analysis

The standard β coefficients and their standard errors for each independent predictor variable as determined *via* univariate analysis are shown in Tables 2 and 3 for the maxillary and mandibular arches, respectively. The predicted expansion per aligner was associated with the predictability of the upper and lower first permanent molars, second primary molars, and upper primary canines. The number of attachments was associated with the predictability of the upper first permanent and second primary molars.

The results of the multivariate linear regression analysis are presented in Table 4 and Fig. 3. The predictability of expansion in the upper first permanent molar significantly increased when one attachment at the buccal surface ($p = 0.017$) or two attachments at the buccal and palatal surfaces ($p < 0.001$) were placed on the bilateral teeth compared to the case without attachment. The predictability decreased significantly as the amount of predicted expansion per aligner increased ($p < 0.001$). In the case of the maxillary second primary molars, the predictability increased when two attachments were placed on the buccal and palatal surfaces of the bilateral teeth compared to the case without attachment ($p < 0.001$), and the predictability decreased significantly as the amount of predicted expansion per aligner increased ($p = 0.014$).

4. Discussion

Several studies have suggested that in children, compared to orthodontic treatment using fixed appliances clear aligners

TABLE 1. Distribution of study population according to teeth and clinical variables.

	Maxillary teeth				Mandibular teeth			
Variables	53–63 n = 55	54–64 n = 46	55–65 n = 79	16–26 n = 90	73–83 n = 31	74–84 n = 51	75–85 n = 80	36–46 n = 90
Gender								
Boys	25	18	40	42	15	24	38	42
Girls	30	28	39	48	16	27	42	48
Age (yr)*	8.03 (0.70)	8.08 (0.79)	8.26 (0.89)	8.42 (0.93)	8.01 (0.82)	8.00 (0.67)	8.33 (0.87)	8.42 (0.93)
Number of pulp treated tooth								
0	53	36	62	90	31	30	58	90
1	2	10	13	0	0	13	20	0
2	0	0	4	0	0	8	2	0
Number of crown restoration								
0	53	29	60	90	31	27	50	90
1	2	9	13	0	0	7	26	0
2	0	8	6	0	0	17	4	0
Number & position of attachment								
No attachment	13	6	9	14	4	9	4	13
1/buccal/unilateral	5	6	9	0	4	3	11	0
1/buccal/bilateral	37	34	48	59	23	39	65	60
2/buccal, palatal/bilateral	0	0	13	17	0	0	0	17
Number of eruption compensation well								
0	16	16	32	38	26	40	46	45
1	10	10	18	20	5	11	21	24
2	24	20	24	24	0	0	11	14
3	5	0	5	8	0	0	2	7
Predicted expansion (mm)*	5.75 (1.69)	3.99 (1.51)	3.68 (1.09)	2.56 (1.17)	2.77 (1.34)	4.48 (1.86)	4.20 (1.48)	2.87 (1.00)
Number of aligner*	25.09 (7.18)	23.54 (7.20)	25.26 (7.19)	25.11 (6.59)	25.11 (5.82)	24.33 (7.36)	25.11 (6.59)	25.11 (6.59)

**Values are presented as mean (standard deviation).*

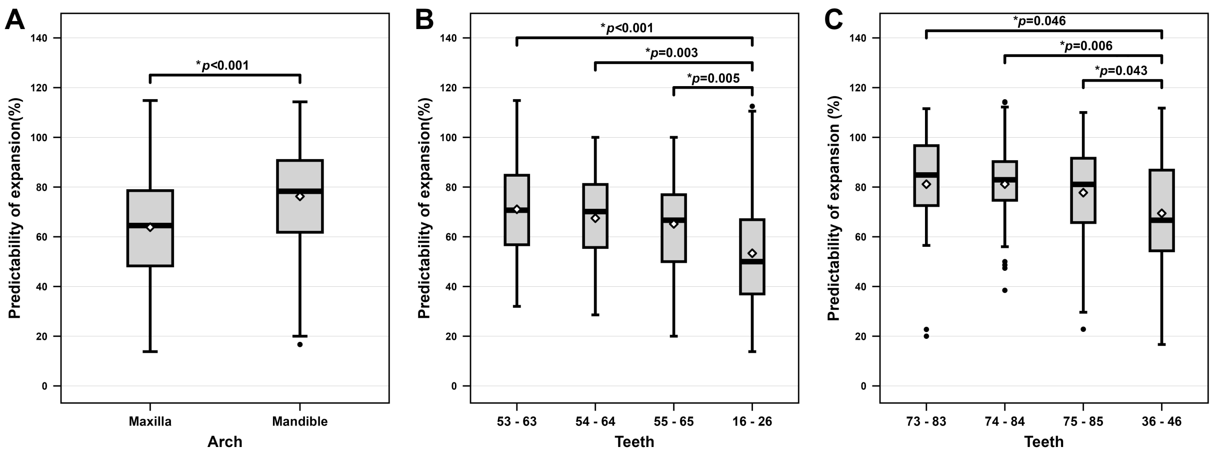

FIGURE 2. Box plot of predictability for arch expansion achieved by Invisalign First system. (A) Predictability difference according to arch type (t-test). (B) Predictability difference according to maxillary teeth (ANOVA and Tukey's *post-hoc* test). (C) Predictability difference according to mandibular teeth (ANOVA and Tukey's *post-hoc* test). $^*p < 0.05$.

TABLE 2. Univariate linear regression analyses for predictability of maxillary arch expansion achieved by Invisalign First system.

Variables	Maxillary teeth							
	53–63		54–64		55–65		16–26	
	b (SE)	*p*-value	b (SE)	*p*-value	b (SE)	*p*-value	b (SE)	*p*-value
Gender								
Boys	reference		reference		reference		reference	
Girls	2.80 (5.32)	0.60	0.03 (5.54)	0.99	−0.51 (4.09)	0.90	−5.99 (5.41)	0.27
Age (yr)	2.78 (3.80)	0.47	3.50 (3.43)	0.31	2.70 (2.31)	0.24	−0.23 (3.31)	0.94
Number of pulp treated tooth								
0	reference		reference		reference			
1	−15.63 (14.02)	0.27	−7.20 (6.73)	0.29	−6.54 (5.68)	0.25		
2					−14.29 (12.44)	0.25		
Number of crown restoration								
0	reference		reference		reference			
1	−15.63 (14.02)	0.27	1.20 (6.99)	0.86	−4.25 (5.21)	0.42		
2			−6.77 (7.32)	0.36	−10.30 (7.46)	0.17		
Number & position of attachment								
No attachment	reference		reference		reference		reference	
1/buccal/unilateral	7.02 (10.40)	0.50	−5.43 (10.67)	0.61	−3.66 (7.79)	0.62		
1/buccal/bilateral	0.09 (6.37)	0.99	−3.18 (8.19)	0.70	4.55 (5.73)	0.43	14.50 (7.37)	0.05
2/buccal, palatal/bilateral					25.89 (6.84)	<0.01*	25.20 (8.95)	0.01*
Number of eruption compensation well								
0	reference		reference		reference		reference	
1	1.23 (7.86)	0.88	−13.02 (7.13)	0.08	−3.75 (5.57)	0.50	4.94 (7.13)	0.49
2	3.74 (6.30)	0.56	−2.86 (5.98)	0.64	−8.19 (4.86)	0.10	−5.71 (6.72)	0.40
3	−12.78 (10.00)	0.21			−12.42 (6.94)	0.08	1.57 (10.03)	0.88
Predicted expansion per aligner	−73.24 (30.43)	0.02*	8.80 (37.01)	0.81	−91.10 (40.02)	0.03*	−134.28 (37.01)	<0.01*

*p value from univariate linear regression analysis. *p < 0.05. SE: standard error.*

TABLE 3. Univariate linear regression analyses for predictability of mandibular arch expansion achieved by Invisalign First system.

Variables	Mandibular teeth							
	73–83		74–84		75–85		36–46	
	b (SE)	*p*-value	b (SE)	*p*-value	b (SE)	*p*-value	b (SE)	*p*-value
Gender								
Boys	reference		reference		reference		reference	
Girls	−12.16 (8.46)	0.16	0.95 (4.85)	0.85	−2.15 (4.14)	0.61	−7.16 (4.96)	0.15
Age (yr)	1.64 (5.47)	0.77	−0.36 (3.66)	0.92	2.93 (2.41)	0.23	3.75 (2.68)	0.17
Number of pulp treated tooth								
0			reference		reference			
1			3.02 (5.78)	0.60	−1.38 (4.79)	0.77		
2			3.65 (6.93)	0.60	14.79 (13.28)	0.27		
Number of crown restoration								
0			reference		reference			
1			−1.55 (7.37)	0.84	3.27 (4.49)	0.47		
2			3.66 (5.38)	0.50	−1.67 (9.65)	0.86		
Number & position of attachment								
No attachment	reference		reference		reference		reference	
1/buccal/unilateral	9.95 (23.67)	0.68	7.90 (11.24)	0.49	9.39 (10.60)	0.38		
1/buccal/bilateral	4.10 (17.49)	0.82	−8.00 (6.23)	0.21	−0.69 (9.36)	0.94	4.41 (10.04)	0.66
2/buccal, lingual/bilateral							12.58 (10.91)	0.25
Number of eruption compensation well								
0	reference		reference		reference		reference	
1	−6.66 (13.93)	0.64	0.80 (5.89)	0.89	1.64 (4.85)	0.74	1.36 (5.84)	0.82
2					7.15 (6.13)	0.25	11.27 (7.56)	0.14
3					−14.86 (13.30)	0.27	15.38 (12.82)	0.23
Predicted expansion per aligner	67.59 (73.86)	0.37	28.12 (27.73)	0.32	−77.75 (34.73)	0.03*	−144.42 (54.17)	0.01*

*p value from univariate linear regression analysis. *p < 0.05. SE: standard error.*

TABLE 4. Multivariate linear regression analysis for predictability of arch expansion achieved by Invisalign First system.

Variables	16–26		55–65	
	b (SE)	*p*-value	b (SE)	*p*-value
Number & Position of attachment				
No attachment	reference		reference	
1/buccal/unilateral			−2.82 (7.20)	0.697
1/buccal/bilateral	16.06 (6.62)	0.017	5.47 (5.55)	0.328
2/buccal, palatal/bilateral	33.48 (8.22)	<0.001	26.33 (6.62)	<0.001
Predicted expansion per aligner	−166.54 (35.34)	<0.001	−88.07 (35.04)	0.014

p value from multivariate linear regression analysis.

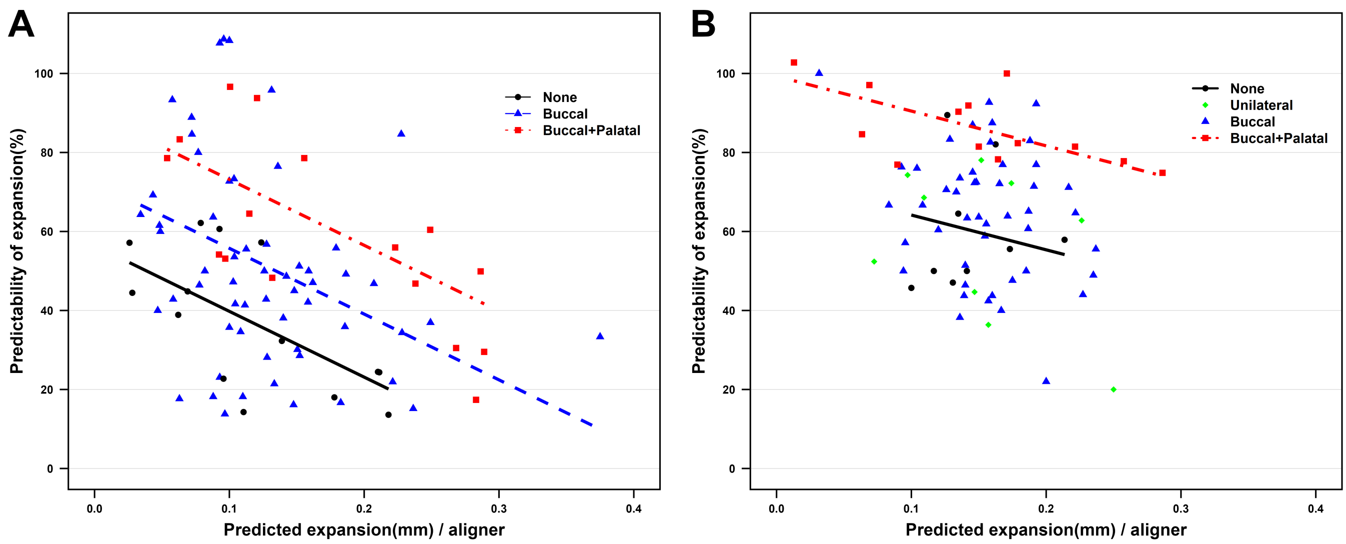

FIGURE 3. Distribution of predictability of arch expansion according to the amount of predicted expansion per aligner and the number and position of attachment. (A) Distribution and result of multivariate linear regression analysis on maxillary first permanent molar. (B) Distribution and result of multivariate linear regression analysis on maxillary second primary molar.

might have distinct advantages such as less discomfort [10], less difficulty in eating, easier adaptation to the appliance, improved oral hygiene [18], fewer emergency visits [19], fewer missed school days, and increased self-perception of attractiveness [20]. If the predictability of arch expansion using clear aligners and the clinical variables that influence it can be identified, more comfortable and efficient orthodontic treatments can be offered to children. Therefore, this study aimed to assess the predictability of arch expansion and evaluate the clinical factors affecting it in children with early mixed dentition stage treated with Invisalign First® system.

In this study, clinical variables that could affect tooth movement were selected and examined to determine whether they had a significant effect on arch expansion using clear aligners. Among the primary teeth included in this study, those previously treated with pulpectomy using Vitapex were taken into consideration. Pulpectomy using Vitapex may affect root resorption compared to untreated teeth, which can also impact tooth movement [21, 22]. Crown restoration has a material and crown shape different from that of non-treated teeth, which can also affect tooth movement [23]. Eruption compensation well is a specific feature included in the Invisalign First® system, which allows for the eruption of permanent teeth by using algorithms to predict the size and shape of the teeth [24]. For children in the mixed dentition stage, the permanent teeth do not erupt or partially erupt during treatment; therefore, an eruption compensation well is often included in the aligner design. If the number of eruption compensation wells is increased in the aligner design, this may be related to the retention and deformation of the aligner, which may affect tooth movement. The number and location of attachments has been recognized as an important factor for efficient tooth movement in previous studies [25, 26]. The amount of planned tooth movement per aligner has also been identified as an important factor for movement efficiency in other studies [27].

Regarding the average predictability of arch expansion, expansion in the maxillary arch was generally less predictable than that in the mandibular arch. These findings align with recent studies on arch expansion [12, 13]. This may be due to differences in the buccal-lingual inclination of the upper and lower posterior teeth. The lower posterior teeth are inclined more lingually relative to the occlusal surface compared to the maxillary posterior teeth, especially in children [28]. Studies have reported that the accuracy of arch expansion increases with the initial negative torque of the posterior teeth [14]. However, these findings differ from those reported by Gonçalves *et al.* [17], who found that the predictability of mandibular arch expansion is less than that of the maxillary arch in patients with mixed dentition. This difference in tendency may be attributed to differences in the age distribution of the samples included in the studies, variation in the amount of arch expansion, the number of aligners used, and the attachment design during treatment planning. The expansion across the first permanent molars was significantly less predictable in both arches. These findings are similar to those of other studies in that the predictability of expansion is greatly reduced in the terminal tooth [12–14]. This may be due to the limited ability of an aligner to exert orthodontic forces on the terminal tooth, along with the increased root length of the first permanent molars compared to other primary teeth in children.

The results of linear regression analyses revealed that the amount of predicted expansion per aligner was associated with the predictability of upper and lower permanent first molars, second primary molars, and upper primary canines. These findings are similar to those reported by Zhou and Guo [14], who found that the efficiency of tooth movement decreased as the amount of designed expansion increased. If the amount of expected tooth movement per aligner is increased, a force greater than that required for optimal tooth movement may be applied to the teeth [29]. Additionally, the fit of the aligner to the tooth may decrease as more deformation occurs in the aligner. These effects may decrease the predictability of arch expansion.

The number and position of attachments were also associated with the predictability of the expansion of the upper permanent first and primary second molars. Several studies have highlighted the importance of attachment in enhancing tooth movement [25, 27]. The attachments of both the buccal and palatal surfaces of the maxillary posterior teeth can increase the retention of the aligner and help move the teeth more accurately in the horizontal direction [30]. The significant effect of the number of attachments in the maxillary teeth may be due to the disadvantage of retention according to the positional characteristics of the aligners in the maxilla. In addition, this study reported that the predictability of maxillary tooth movement was lower than that of the mandibular teeth; therefore, the effect of the attachment may be more important for maxillary teeth.

One limitation of the present study was that it did not consider the effect of growth on the expansion of the arch. This study was conducted in children aged 7–9 years, and it is possible that transverse growth occurred. However, in this study, the mean interval between before and after treatment with an aligner was 7 months, allowing for less than 0.5 mm spontaneous transverse growth in the maxillary arch for this age group [31]. Another limitation was that the cause of the change was not identified by measuring the amount of expansion achieved (posttreatment arch width - initial arch width) after treatment. During the process of arch expansion in children, changes in arch width can be caused by bodily movement or buccal tipping of the tooth. It has been reported by several studies that arch expansion using Invisalign® is mostly by buccal tipping rather than bodily movement of the tooth [12, 14]. In the cases included in this study, buccal root torque was applied to the teeth according to the same criteria as one operator from the treatment plan to prevent side effects caused by such movements and to move the teeth as much as possible. For a more accurate analysis of tooth movement, measurement of changes at an additional reference point close to the center of resistance of the teeth, or analysis through 3D images, such as cone beam computed tomography, might be required. Furthermore, the patients participating in this study followed the 7-day aligner change protocol, which has been shown to have lower accuracy compared to the 14-day aligner change protocol when accompanied by buccal crown torque and other complex tooth movements [32].

Despite these limitations, the significance of this study is that it presented the predictability of arch expansion through the values of the arch width table of ClinCheck®, which can be easily confirmed. During treatment using Invisalign®, the operator establishes a treatment plan using the ClinCheck® software. If the actual amount of expansion can be predicted through the values of the arch width table, which can be easily checked by the program, it may be helpful in determining the amount of overexpansion or the need for an additional aligner. In addition, we analyzed whether various objective clinical variables commonly encountered when establishing a treatment plan using the Invisalign First® system in children could affect the predictability of arch expansion. Based on the results of this study, if the planned amount of arch expansion increases, the number of aligners can also increase. In addition, increasing the number of attachments may also be considered for more efficient expansion of the maxillary first permanent and second primary molars.

5. Conclusions

When arch expansion is planned in children with early mixed dentition and treated with the Invisalign First® system, the mean predictability was lower in the maxillary arch compared to the mandibular arch, and lower in the first permanent molar compared to the primary canine and first and second primary molars in both the arches. The amount of predicted expansion per aligner and the number of attachments to the maxillary teeth are potential clinical factors that can affect the predictability of arch expansion. If a treatment plan for arch expansion is established considering the accuracy and clinical factors that can affect it, a more efficient and accurate treatment can be performed.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article.

AUTHOR CONTRIBUTIONS

CHK, SJM and JSS—designed the study. CHK and SJM—performed the research, analyzed the data. CMK—provided help and advice for the research. CHK and JSS—prepared the manuscript. All authors contributed to the editorial changes in the manuscript. All the authors have read and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted following the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board (approval no. IRB 2-2023-0020) at Yonsei University Dental Hospital, Seoul, Korea. Patient informed consent was waived due to the study's retrospective nature.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] McNamaraa JA. Maxillary transverse deficiency. American Journal of Orthodontics and Dentofacial Orthopedics. 2000; 117: 567–570.

[2] Krishnan V, Daniel ST, Lazar D, Asok A. Characterization of posed smile by using visual analog scale, smile arc, buccal corridor measures, and modified smile index. American Journal of Orthodontics and Dentofacial Orthopedics. 2008; 133: 515–523.

[3] Pinho T, Rocha D, Ribeiro S, Monteiro F, Pascoal S, Azevedo R. Interceptive treatment with Invisalign® First in moderate and severe cases: a case series. Children. 2022; 9: 1176.

[4] Melsen B. Northcroft lecture: how has the spectrum of orthodontics changed over the past decades? Journal of Orthodontics. 2011; 38: 134–143.

[5] Cong A, Ruellas ACDO, Tai SK, Loh CT, Barkley M, Yatabe M, *et al*. Presurgical orthodontic decompensation with clear aligners. American Journal of Orthodontics and Dentofacial Orthopedics. 2022; 162: 538–553.

[6] Ojima K, Dan C, Kumagai Y, Watanabe H, Nanda R. Correction of severe crowding in teenage patients using the Invisalign system. Journal of Clinical Orthodontics. 2020; 54: 383–391.

[7] Dai F, Xu T, Shu G. Comparison of achieved and predicted crown movement in adults after 4 first premolar extraction treatment with Invisalign. American Journal of Orthodontics and Dentofacial Orthopedics. 2021; 160: 805–813.

[8] Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. The Angle Orthodontist. 2015; 85: 881–889.

[9] Azaripour A, Weusmann J, Mahmoodi B, Peppas D, Gerhold-Ay A, Van Noorden CJF, *et al*. Braces versus Invisalign®: gingival parameters and patients' satisfaction during treatment: a cross-sectional study. BMC Oral Health. 2015; 15: 69.

[10] Cardoso PC, Espinosa DG, Mecenas P, Flores-Mir C, Normando D. Pain level between clear aligners and fixed appliances: a systematic review. Progress in Orthodontics. 2020; 21: 3.

[11] Lynch NM, Shroff B, Carrico CK, Sawicki V, Sabol M, Lindauer SJ. Clear aligner therapy in the mixed dentition: indications and practitioner perspectives. American Journal of Orthodontics and Dentofacial Orthopedics. 2023; 164: 172–182.

[12] Houle J, Piedade L, Todescan R, Pinheiro FHSL. The predictability of transverse changes with Invisalign. The Angle Orthodontist. 2017; 87: 19–24.

[13] Tien R, Patel V, Chen T, Lavrin I, Naoum S, Lee RJH, *et al*. The predictability of expansion with Invisalign: a retrospective cohort study. American Journal of Orthodontics and Dentofacial Orthopedics. 2023; 163: 47–53.

[14] Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. The Angle Orthodontist. 2020; 90: 23–30.

[15] Lione R, Paoloni V, Bartolommei L, Gazzani F, Meuli S, Pavoni C, *et al*. Maxillary arch development with Invisalign system. The Angle Orthodontist. 2021; 91: 433–440.

[16] Lione R, Cretella Lombardo E, Paoloni V, Meuli S, Pavoni C, Cozza P. Upper arch dimensional changes with clear aligners in the early mixed dentition. Journal of Orofacial Orthopedics. 2023; 84: 33–40.

[17] Gonçalves A, Ayache S, Monteiro F, Silva FS, Pinho T. Efficiency of Invisalign First® to promote expansion movement in mixed dentition: a retrospective study and systematic review. European Journal of Paediatric Dentistry. 2023; 24: 112–123.

[18] Abbate GM, Caria MP, Montanari P, Mannu C, Orrù G, Caprioglio A, *et al*. Periodontal health in teenagers treated with removable aligners and fixed orthodontic appliances. Journal of Orofacial Orthopedics. 2015; 76: 240–250.

[19] Gou Y, Ungvijanpunya N, Chen L, Zeng Y, Ye H, Cao L. Clear aligner *vs.* fixed self-ligating appliances: orthodontic emergency during the 2020 coronavirus disease 2019 pandemic. American Journal of Orthodontics and Dentofacial Orthopedics. 2022; 161: e400–e406.

[20] Sharma R, Drummond R, Wiltshire W, Schroth R, Lekic M, Bertone M, *et al*. Quality of life in an adolescent orthodontic population. The Angle Orthodontist. 2021; 91: 718–724.

[21] Nakornchai S, Banditsing P, Visetratana N. Clinical evaluation of 3Mix and Vitapex as treatment options for pulpally involved primary molars. International Journal of Paediatric Dentistry. 2010; 20: 214–221.

[22] Chen X, Liu X, Zhong J. Clinical and radiographic evaluation of pulpectomy in primary teeth: a 18-months clinical randomized controlled trial. Head & Face Medicine. 2017; 13: 12.

[23] Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. American Journal of Orthodontics and Dentofacial Orthopedics. 2009; 135: 27–35.

[24] Tuncay O, Bowman SJ, Amy B, Nicozisis J. Aligner treatment in the teenage patient. Journal of Clinical Orthodontics. 2013; 47: 115–119; quiz 140.

[25] Jones ML, Mah J, O'Toole BJ. Retention of thermoformed aligners with attachments of various shapes and positions. Journal of Clinical Orthodontics. 2009; 43: 113–117.

[26] Jedliński M, Mazur M, Greco M, Belfus J, Grocholewicz K, Janiszewska-Olszowska J. Attachments for the orthodontic aligner treatment-state of the Art-A comprehensive systematic review. International Journal of Environmental Research and Public Health. 2023; 20: 4481.

[27] Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique—regarding incisor torque, premolar derotation and molar distalization. BMC Oral Health. 2014; 14: 68.

[28] Marshall S, Dawson D, Southard KA, Lee AN, Casko JS, Southard TE. Transverse molar movements during growth. American Journal of Orthodontics and Dentofacial Orthopedics. 2003; 124: 615–624.

[29] Li X, Ren C, Wang Z, Zhao P, Wang H, Bai Y. Changes in force associated with the amount of aligner activation and lingual bodily movement of the maxillary central incisor. The Korean Journal of Orthodontics. 2016; 46: 65.

[30] Fan D, Liu H, Yuan CY, Wang SY, Wang PL. Effectiveness of the attachment position in molar intrusion with clear aligners: a finite element study. BMC Oral Health. 2022; 22: 474.

[31] Bishara SE, Ortho D, Jakobsen JR, Treder J, Nowak A. Arch width changes from 6 weeks to 45 years of age. American Journal of Orthodontics and Dentofacial Orthopedics. 1997; 111: 401–409.

[32] Al-Nadawi M, Kravitz ND, Hansa I, Makki L, Ferguson DJ, Vaid NR. Effect of clear aligner wear protocol on the efficacy of tooth movement. The Angle Orthodontist. 2021; 91: 157–163.

How to cite this article: Chi Hoon Kim, Sang-Jin Moon, Chung-Min Kang, Je Seon Song. The predictability of arch expansion with the Invisalign First system in children with mixed dentition: a retrospective study. Journal of Clinical Pediatric Dentistry. 2024; 48(1): 91-100. doi: 10.22514/jocpd.2024.012.